Dried Cottage Cheese Whey: *Review of Its Composition and Use in Bakery Products*

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INCREASING production of cheeses in the United States has resulted in surpluses of whey, with accompanying problems in utilization and disposal. Although sweet whey, a byproduct of Cheddar and Swiss cheese manufacture, is used in sizeable and increasing amounts, acid whey, a byproduct of cottage cheese manufacture, finds small use. Of the estimated 365 million pounds dry weight equivalent of acid whey solids produced in 1975 (1), only 6.2 million pounds were utilized for food and a like amount for animal feed (2). A large percentage of the acid whey utilized in human foods is used by bakeries as dried whey, condensed whey, or blends with protein supplements. Some of the problems of drying and utilizing acid whey are that small processors have difficulty in economically processing whey in evaporators and dryers, or they are too distant from a larger plant having centralized whey processing capabilities.

This paper describes some of the uses for acid whey in bakery products. Its composition and nutritional quality are reported together with the necessary processing treatment required to render it acceptable for bread baking.

Table I
Average Percentage Composition of Nonfat Dry Milk and Dried Cheese Wheys[1]

	Per Cent						
	Fat	Lactose	Total Protein	Ash	Ca	P	Lactic Acid
NDM	0.7	51.6	35.8	7.9	1.30	1.0	—
Acid whey	0.8	67.7	11.4	10.9	1.78	1.13	4.8
Sweet whey	0.8	72.1	12.8	7.9	0.62	0.77	1.1

[1]Reference (3).

Composition

Whey is the watery residue obtained after separation of the milk curd or cheese and consists of 4.5 to 5.0 per cent lactose, 0.6 to 0.9 per cent protein, and 0.5 to 0.8 per cent ash. **Table I** compares the composition of nonfat dry milk (NDM) with that of dried acid and sweet whey. NDM has about three times the protein and one-third less lactose than whey. Acid and sweet wheys differ in composition because of differences in cheese making processes (3). Cottage cheese requires a longer fermentation time than that used to produce Cheddar or Swiss cheeses, and consequently more of the lactose in acid whey is converted to lactic acid, resulting in a lower pH (4.6 vs. 6.0). More calcium and phosphorus are stripped from casein, resulting in a higher ash content for acid whey, and on a dry weight basis the Ca and P even exceed the amounts in NDM. Considerable amounts of acid whey are now produced from direct acidification of skim milk at low temperatures with hydrochloric acid and then heating to induce coagulation, or the addition of food grade phosphoric, citric, or lactic acids to a pH slightly higher than needed to cause coagulation, followed by the addition of D-glucono delta-lactone for final acidification (4). These acidulants are approved in the standards of identity for cottage cheese.

Nutritional Value

Nonfat dry milk or casein derived

from it is considered to be of excellent nutritive value with a protein efficiency ratio (PER), expressed as grams gain per gram of protein consumed, of 2.5 or more. The nutritive value of whey protein concentrates (WPC) is also excellent. The nutritive value of acid reverse osmosis (RO) WPC (21 per cent protein) mixed with bulgar wheat exceeds that of a blend of NDM and wheat (5), and the PER's of undenatured WPC (6) and denatured acid WPC (7) exceed that of casein **(Table II).** The amounts of protein and its amino acid composition in sweet and acid wheys are similar; lysine values for casein and whey protein are similar, although other essential amino acids may vary slightly (8).

Denaturation of Protein

Milk solids for bread baking should be made from fluid milk sufficiently heated to denature 80 to 85 per cent of its serum proteins to promote high absorption and prevent slackness of doughs and volume depressing effects. A milk suitable for baking should have Harland and Ashworth values of 1.5 mg or less of undenatured whey protein nitrogen/g nonfat milk solids (9). These values for whey solids are slightly higher because the whey protein is more concentrated after the casein has been removed. Although the proteins of sweet whey or skim milk required 30 minutes treatment at 85° C, the proteins of acid whey, because of its acidity, require heating at 90-95° C for 30 minutes to denature 85 per cent of the serum protein (10). Whey produced by direct acidification of skim milk to pH 4.6 with either lactic or hydrochloric acid requires similar heat treatments. Accurate determinations of undenatured whey protein by the Harland and Ashworth procedure require adjustment of the pH of the acid whey to 6.0 before saturation with sodium chloride.

Effect on Sponge Doughs

Acid whey, whether added singly or in combination with skim milk solids, produces changes in dough behavior and bread characteristics. It imparts good tolerance to water absorption and extends the mixing requirements of doughs, produces bread of good taste acceptability and of improved grain and keeping qualities, even though it slightly restricts loaf volume. Farinograph water absorption is slightly lowered, peak time is slightly increased, and mixing tolerance is extended.

High heat treatment of acid whey prior to its condensing and drying improves the loaf volume of bread made from hard red spring wheat flour (HRS), and extended mixing improves the volumes of bread with either high or low heat-treated wheys **(Table III)** (11). The table shows that absorption variations

Table II
Protein Efficiency Ratio (PER) of Whey Protein Concentrate (WPC) Compared to Casein and Nonfat Dry Milk (NDM)

	PER
Wheat (W)[5]	0.91
W + RO whey (21 per cent protein)	3.31
W + NDM	3.03
WPC (57 per cent protein)[6]	3.1
Casein	2.5
Acid WPC (65 per cent protein)[7]	
Air dry 82°C	3.03
Spray dry 235 to 265°C	2.90
Spray dry 200 to 235°C	2.84

Superscripts refer to reference numbers.

Table III
Effect of Heat Treatment of Acid Whey Prior to Condensing and Drying on the Loaf Volume of Brands Made from Hard Red Spring Wheat Flour Doughs Proofed 60 Minutes

Minutes Mixing Time	cc Loaf Volume/g					
	4.3 Per Cent Low Heat Acid Whey[1]			4.3 Per Cent High Heat Acid Whey[2]		
	Per Cent Absorption			Per Cent Absorption		
	56.5	58.5	60.5	56.5	58.5	60.5
3.5	5.18	5.26	5.38	5.52	5.51	5.40
6	6.02	5.88	5.74	5.90	6.19	6.15
8.5	6.22	6.03	6.00	6.42	6.31	6.49

[1]77°C, 16 seconds, 11.5 mg whey protein N/g dry whey.
[2]91°C, 30 minutes, 2.2 mg whey protein N/g dry whey.
Absorption differences nonsignificant ($P > .05$).
Mixing times significantly different ($P < .01$).
Wheys significantly different ($P < .01$).

Table IV
Effect of Heat Treatment of Aid Whey Prior to Condensing and Drying on the Baking Characteristics of Doughs Made with Hard Red Spring Wheat Flour

% Dry Whey Added	Heat Treatment of Whey	Proof Time (Minutes to 5/8 inch)	Loaf Volume cc/100 g	Bread Score	Grain Score
0	—	64[a]	704[a]	63.6	17.2[a]
4.3	77°C, 16 sec.	71[b]	631[b]	64.1	18.1[b]
4.3	91°C, 30 min.	72[b]	674[c]	64.0	18.1[b]

Different superscript letters — significantly different ($P < .05$).

Table V
Effect of Different Mixing Times and Absorptions on the Baking Quality of Doughs Containing 4% NDM[1] and 2% Acid Whey

Minutes Mixing Time	Hard Red Winter Wheat Flour[2]					
	cc Loaf Volume		Grain Scores		Total Scores	
	6% NDM	Test	6% NDM	Test	6% NDM	Test
4	2675	2462	17.4	18.2	89.2	87.6
6	2686	2675	17.0	18.0	88.6	90.0
8	2640	2709	17.0	17.2	87.5	89.3
	Hard Red Spring Wheat Flour[3]					
62	2708	2746	16.2	17.2	88.0	89.8
66	2851	2738	16.4	17.4	89.4	90.0
70	3003	2703	16.4	17.3	92.1	89.5

[1]NDM — Nonfat dry milk.
[2]61, 64.5, and 68% dough absorptions.
[3]3, 6, and 9 minutes mixing times.

Table IX
Effect of Mixing Time on the Baking Quality of Sour Doughs

Minutes Mixing Second Speed	Dough Temperature, °F	Specific Volume cc/g Bread	Grain Score
6	85	2.89	open
8	86	3.20	open
10	87	3.34	open
12	87	3.69	very open
15	87	3.84	very open

acid, vinegar, or other acidulants are being used in English muffins, in which additional sourness is desirable (21). Such mixtures should also contribute to the shelf life of muffins with a high moisture content that makes them susceptible to microbial deterioration unless special precautions are taken.

Replacement of 14 per cent skim milk solids with dry acid whey in a high ratio devil's food cake formula produced more tender but fragile cakes of darker color (22). Volumes were similar and, in some instances, taste scores were higher. Additional soda was added to the cakes containing acid whey to neutralize the lactic acid and adjust the pH above 8.0. Acid whey also accentuates spice as well as chocolate flavor in cakes (23). A firm yet tender devil's food cake of good volume can be produced by decreasing the shortening by 30 per cent and sugar by 10 per cent when including acid whey and holding the other ingredients constant (11). Tender and yet firm yellow layer cakes can be made with sweet whey if the sugar and shortening levels are reduced (24).

Taste preference scores of commercial lemon pudding showed mixes containing one ounce of dry acid whey to four ounces of dry pudding mix reconstitute with water, egg yolk, sugar, and then heated, significantly improved the taste of the pudding with no change of viscosity (22). Baking of fruit-type pies in which acidity is important might also benefit from the incorporation of acid whey.

Conclusions

Cottage cheese whey is commercially available in the dried form and because of its low cost (10 to 12 cents per pound) should be economically attractive to the baking industry. Acid whey could find extensive uses in sour dough type products, whose market potential is expanding.

The highly nutritious acid whey protein, because of its good baking qualities as a concentrate, could be used in high-protein breads for the world market. Whey protein concentrates are commercially available, and increased production is foreseen as new uses for specific types are developed.

The use of low levels of acid whey by itself or in blends with nonfat milk solids or casein, as is customary in commercial processing, should permit a more economical baked product with minimal change of characteristics of the finished goods. By use of higher levels of acid whey, alone or as a replacement for skim milk solids, further economies would be realized, with added advantages of more tolerance to water absorption and mixing and, for the finished product, a softer bread of improved keeping quality and better grain. More tender cakes of improved color and accentuated spice and chocolate flavors are produced by the use of acid whey. Addition of acid whey to lemon-flavored puddings increased their flavor score without changing viscosity characteristics.

For purposes of ingredient labeling, acid whey whether neutralized or not is covered by the terms whey or dried whey. At present there are no standards of identity for dried acid whey.

References

(1) Dairy Situation. ERS-USDA, DS 361, p. 36, July (1976).

(2) Clark, W. S., Jr. Proceedings of Whey Products Conference, ARS-NE-81 7, (1977).

(3) Mavropoulou, I. P., and Kosikowski, F. V. *J. Dairy Sci.* 56(9), 1128 (1973).

(4) Ernstrom, C. A., and Kale, C. G. *J. Dairy Sci.* 58(7), 1008 (1975).

(5) Womack, M., and Vaughan, D. H. *J. Dairy Sci.* 55(8), 1081 (1972).

(6) Wingerd, W. H., Saperstein, S., and Lutwak, L. *Food Tech.* 24(7), 758 (1970).

(7) Panzer, C. C., Schoppet, E. F., Sinnamon, H. I., and Aceto, N. C. *J. Food Sci.* 41, 1293 (1976).

(8) Mavropoulou, I. P., and Kosikowski, F. V. *J. Dairy Sci.* 56(9), 1135 (1973).

(9) Harland, H. A., and Ash-Pallansch, M. J. *J. Dairy Sci.* 50(6), 828, (1967).

(10) Guy, E. J., Vettel, H. E., and worth, U. S. *Food Res.* 12, 247 (1947).

(11) Guy, E. J. Unpublished data.

(12) Guy, E. J. Proceedings of the Whey Products Conference, ERRC Publ. No. 3779, p. 37 (1972).

(13) Guy, E. J., Vettel, H. E., and Pallansch, M. J. *Bakers Digest* 41(3), 44 (1967).

(14) Guy, E. J. Vettel, H. E., and Pallansch, M. J. *Ibid* 45(3), 43 (1971).

(15) Guy, E. J., Vettel, H. E., and Pallansch, M. J. *Cereal Sci. Today* 19 (12), 551 (1974).

(16) Shenkenberg, D. R., Barnes, F. G., and Guy, E. J. *Food Prod. Dev.* 6(1), 29 (1972).

(17) Barnes, F. G., Shenkenberg, D. R., and Guy, E. J. *Bakers Digest* 47(3), 16 (1973).

(18) Barnes, F. G., Shenkenberg, D. R., and Guy, E. J. *Ibid* 47(3), 19 (1973).

(19) Shenkenberg, D. R., Barnes, F. G., and Webb, B. H. U.S. Patent 3,826,850 (1974).

(20) Jackel, S. S., and Horn, M. J. *Bakers Digest* 49(3), 38 (1975).

(21) Pfefer, D. N. *Bakers Digest* 50(2), 32 (1976).

(22) Guy, E. J., Vettel, H. E. Pallansch, M. J. *J. Dairy Sci.* 49(6), 694 (1966). Abstract.

(23) Singleton, A. D., Haney, H. N., and Habighurst, A. B. *Cereal Sci. Today* 10(2), 53 (1965).

(24) Best, B. W. *Bakers Digest* 42(3) 38 (1967).

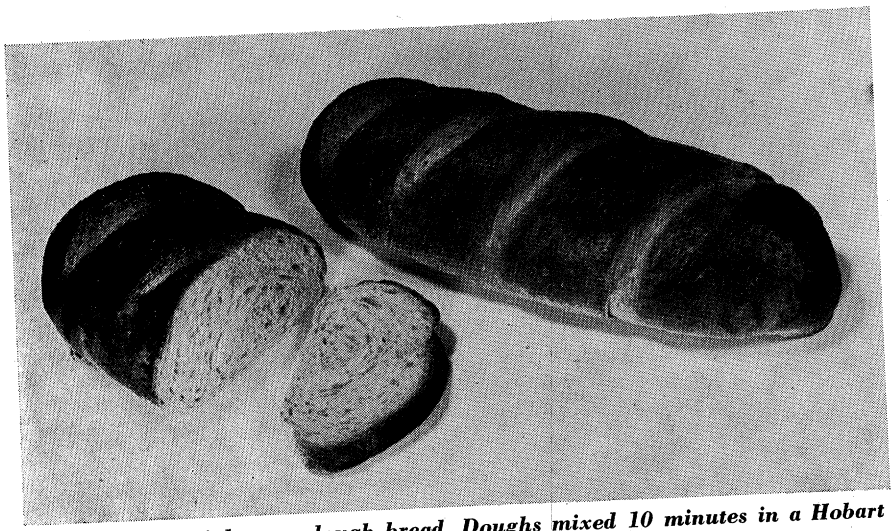

FIGURE 2: *Straight sour-dough bread. Doughs mixed 10 minutes in a Hobart A-200 mixer equipped with a McDuffey bowl and fork.*

Table VII

Sponge Bread Baking Quality of Hard Red Spring Wheat Flour Containing Whey Protein Concentrates (UFG83)

	Control[1] (No supplement)	4% UFG83[2]	6% UFG83[2]	3% NDM[4]
% Dough absorption	60	66	66	62
Specific volume cc/g	6.37	6.36	6.60	6.77
Bread score	59.3	59.3	61.8	61.7
Av. flavor score[3]				
1 day	6.77	6.50	6.89	7.16
3 days	7.00	6.66	6.28	6.66
Av. texture score[3]				
1 day	6.51	7.00	6.63	6.58
3 days	6.52	6.00	6.36	6.73
Av. Compression g load to depress slice 3 mm				
1 day	10.0	6.7	8.5	9.5
3 days	14.3	10.7	12.3	16.7

[1]No Emplex added.
[2]% Expressed on an added protein basis. 0.5% Emplex added.
[3]Nine point hedonic scale.
[4]5% Nonfat dry milk for flavor and texture scores.

Table VIII

Sour Dough Formulation

	Straight Dough	Sponge[1] %	Dough %
Hard red spring wheat flour	100.0	50	50
Water	53.1	30	23.1
Bakers' yeast	4.0	2.5	—
Acid whey powder — high heat	10.5	—	10.5
Vinegar — 50 grain	6.9	—	6.9
Salt	1.5	—	2.0
Shortening	1.0	—	1.0
Malt	1.0	1.0	—
Minutes mixing time[2]	Low, 10 sec.		Low, 6 sec.
Dough temperature °F	90	—	80
Fermentation or floor time, minutes	40	—	30
Intermediate proof, minutes	15	—	15
Proof 95 °F, 90% RH, minutes	60	—	60
Slash surfaces and bake 375 °F for 45 min. in steam oven			

[1]Set 4 hour at 86 °F, 85% RH.
[2]Hobart A-200 mixer with McDuffee bowl and fork.

The Dairy Laboratory of the U.S.D.A. developed these formulations which produce a pleasing, acid tasting, chewey, desirable, open-grained bread that can be made within three hours by a simplified straight dough procedure and seven hours by a sponge and dough procedure (16). Formulations are listed in **Table VIII.** Whey concentrates or dried whey can be used. The level of acidity which suits local taste preferences can be maintained through the addition of more or less acid whey and/or vinegar. A typical formulation has 0.09 to 0.10 meq of acid/g bread with 38 per cent of the acidity as added acetic acid and 62 per cent added lactic acid (as acid whey). The pH's of the breads are 4.6 to 4.7 and specific volumes range from 3.3 to 3.7 cc/g bread. **Figure 2** shows this straight dough bread. Excellent sour dough breads were made in a retail shop by the straight dough procedure, with 16 pound lots of dough mixed in a Hobart A-200 mixer equipped with a 20 quart bowl and dough hook (11). Acceptable open-grained breads were produced by mixing for 10 to 15 minutes and then making up the doughs by hand (**Table IX**).

The use of low energy intermediate-size horizontal mixers in commercial bakeries at 40 to 60 rpm poses problems in mixing of sour doughs (17). Farinograph studies show that combinations of acid, salt, and high levels of lactose all increased dough mixing requirements and that increasing the farinograph speed or the addition of cysteine reduced them. Bread mixing studies with a low energy mixer showed that 80 ppm cysteine reduced the mixing requirements without changing the flavor characteristics of the bread. Withholding the salt until the later stages of mixing also reduced the mixing time (18). The preparation of these doughs is covered by a non-exclusive, royalty-free patent (19).

Other Uses for Acid Whey

A controlled fermentation of acid whey with vinegar followed by spray drying produces a dried dairy culture which functions by increasing specific volumes of some baked goods, improves product uniformity, and decreases the development of mold in stored products (20).

Mixtures of acid whey, lactic

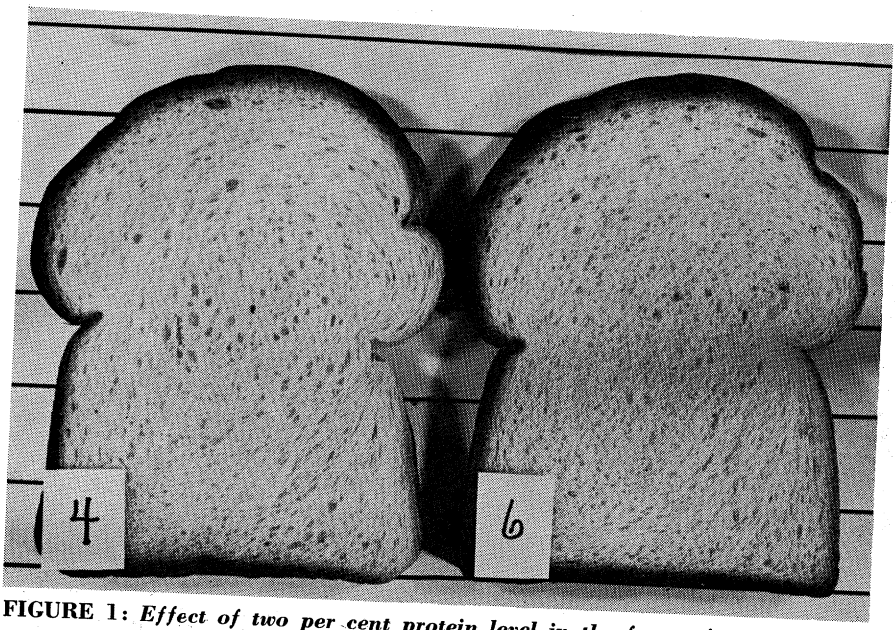

FIGURE 1: *Effect of two per cent protein level in the form of whey protein concentrate on center-cut bread slices. No. 4 = water control. No. 6 = 2.6 per cent UFG 83.*

have little effect on loaf volumes. **Table IV** shows that high heat treatment of the acid whey significantly improves the volume of breads made with HRS doughs proofed to height (12). Both wheys improve bread and grain scores equally but depress volumes and increase proof times when compared to bread and dough to which no whey has been added.

The replacement of one-third of the skim milk solids with acid whey solids in six per cent milk breads (test formula) also extends the mixing requirements of both HRS and hard red winter wheat flour (HRW) and significantly improves their bread grain scores (13). Some of the data, representing averages either at three absorptions or three mixing times, are listed in **Table V.** The test loaves with HRW are equivalent in average volumes and total scores to those containing six per cent NDM when the doughs were mixed from six to eight minutes and four to six minutes, respectively. Although their volumes are lower, the test loaves made with HRS show very significantly greater tolerance to absorption variations with respect to volumes and total scores. This is also the case with HRW doughs, but to a lesser extent. Bread made with test formulas with either HRW or HRS have significantly improved keeping qualities and equivalent panel acceptabilities. Also the addition of lactic acid to NDM bread doughs in amounts equivalent to that supplied by acid whey improves grain scores and decreases the pH of breads similar to test breads made with acid whey. At the three per cent level of total milk solids (three per cent NDM vs. two per cent NDM + one per cent acid whey), characteristics of breads were not significantly different.

Table VI
Effect of Dairy Ingredients on Farinograph Characteristics of Hard Red Winter Wheat Flour Doughs with 2% Salt

Addition	% Absorption[1]	Minutes			Dough pH
		Arrival Time	Peak Time	Stability	
6% NDM[2]	63.9	10.5	20	23.5	5.75
4% NDM[2] + 2% acid whey	60.9	8	21	35	5.40
None	58.9	4.5	13	21	4.75
4.2 sweet whey	58.7	6.5	13.5	24	5.00
4.2% sweet whey + 0.16% lactic acid	56.7	3.0	15.0	39	4.70
4.6% acid whey	57.3	4.0	15.5	37	4.75
6% NDM[2]	64.2	9	15	21	5.50

[1]480 g basis.
[2]Nonfat dry milk.

Effect of Cottage Cheese Whey on Farinograph Characteristics of Doughs

Acid whey lowers farinograph absorption of doughs **(Table VI)** even though the tolerance of doughs to water absorption variations is good. Peak mixing times and stabilities are increased. Addition of lactic acid to sweet whey doughs decreases dough pH and farinograph absorption and increases peak mixing time and stability equivalent to those of acid whey doughs (14).

Effect of Acid Whey Protein Concentrates on Bread Baking Quality

Whey protein concentrates can be made by ultrafiltration, ultrafiltration and gel permeation (UFG), reverse osmosis, or electrodialysis. Several concentrates are available commercially.

Studies with a 62 per cent heat denatured protein concentrate of 83 per cent protein (UFG 83) prepared from cottage cheese whey by ultrafiltration and gel permeation showed it had good sponge bread baking characteristics with HRS (15). Addition of two per cent protein from this preparation produced doughs with four per cent added water absorption and breads of unchanged volumes and panel acceptability, although the breads were slightly firmer by compression tests. **Figure 1** shows bread made with two per cent protein concentrate compared to a control.

Adding four to six per cent protein from UGF 83 to doughs increased dough absorption by six per cent and produced breads of excellent volume and total score providing that 0.5 per cent sodium stearoyl-2 lactylate was added to the doughs **(Table VII).** Flavor and texture scores were similar to one-day-old control and five per cent NDM breads. Texture scores of three-day-old breads were slightly (but not significantly) lower than the controls even though the breads were softer by compression tests.

Use of Acid Whey in Sour Dough Breads

Because of its acidity, cottage cheese whey lends itself to the production of sour dough breads that have typically restricted volumes.